

Remarks

The Applicants have amended the Specification and Abstract to place them into final condition for allowance. Entry into the official file is respectfully requested.

The Applicants have amended Claim 1 to recite that the amount of Si is more than 0.40 to 1.1%. This amendment is inherently supported in view of the original range of 0.30 to 1.1%. Entry into the official file is respectfully requested.

Claims 1-12 and 17-20 stand rejected under 35 U.S.C. §103 over the combination of US '105 with US '358. The Applicants respectfully submit that one skilled in the art would not make the hypothetical combination, but in any event, the combination would still not result in the Applicants' claimed subject matter. Reasons are set forth below.

The Applicants respectfully submit that US '358 does not substantially overlap, component wise, with Claims 1-12 and 17-20. For example, US '358 discloses 0.15 to 0.4% Si. On the other hand the Applicants claims more than 0.4 to 1.1% Si. This means that there is a lack of overlap with respect to all of the claimed elements versus US '358. As a consequence, there is no *prima facie* obviousness.

In any event, US '358 does not disclose the claimed structure of bainite and/or martensite or the total volume fraction of bainite and/or martensite being 10% or more. This is brought about because US '358 employs a completely different manufacturing process to produce those steels. The manufacturing process of US '358 includes spheroidizing, annealing, cold forging, lathe turning component rolling, and induction hardening. Those skilled in the art are well aware of the fact that such a manufacturing process would result in a structure that is not bainite and/or martensite. As a consequence, US '358 inherently fails to provide or disclose a bainite and/or martensite structure having a total volume fraction of 10% or more. US '358 is inapplicable.

The Applicants have factually demonstrated the fact that US '358 does not disclose a bainite and/or martensite structure with the total volume fraction of bainite and martensite being 10% or more. The rejection frankly acknowledges this fact. Instead, the rejection turns to US '105 to cure that deficiency inasmuch as it discusses bainite, among other things. However, it is not the composition of US '105 or the composition of US '358 that necessarily results in the bainite and/or martensite structure. Instead, it is that composition in conjunction with the manufacturing method. The problem with the rejection is that it relies on US '358 for the fundamental composition.

However, the Applicants have already factually demonstrated that it is the manufacturing process that ultimately affects the structure in addition to the composition. In other words, both the composition and the method of producing the item at issue ultimately influence the final product.

The problem with attempting to introduce methodology of US '105 into US '358 is that the characteristics of the US '105 steels are also brought about by both composition and methodology. The problem with that approach is that US '358 and US '105 teach different compositions. For example, US '358 emphasizes that the amount of chromium should be quite low such as not more than 0.10%. On the other hand US '105 actively encourages addition of a significant amount of chromium such as 0.4 to 1.8% to impart strength and hardenability. US '105 specifically states that the strength and hardenability will not be adequate if the Cr content is less than 0.4%. Thus, simply importing the methodology of US '105 into US '358 will not necessarily result in the structure speculated about in the rejection with respect to the presence of bainite and/or martensite because it is not the composition alone that impacts the presence or absence of bainite and/or martensite and it is not the process alone that influences the presence of bainite and/or martensite, but the combination. Therefore, introducing the methodology of US '105 into US '358 does not account for the differences in composition. One skilled in the art would not have a reasonable expectation that the bainite and/or martensite of US '105 would be present in the steels of US '358 having a different composition. The Applicants respectfully submit that one skilled in the art would not make the hypothetical combination. On this basis alone, the Applicants respectfully submit that Claims 1-12 and 17-20 are allowable over US '358 and US '105.

The Applicants respectfully submit that the combination is even less applicable to others of the claims such as Claims 3 and 5 and claims depending from those claims. US '358 does not disclose the structure of bainite and/or martensite and the total volume fraction of bainite and martensite being 10% or more, as claimed by the Applicants in Claims 1-12 and 17-20. From the manufacturing process set out in US '358, namely, spheroidizing annealing → cold forging → lathe turning and component rolling → induction hardening, those skilled in the art know that the structure before induction hardening is not bainite and/or martensite.

The prior austenite grain size of Steel No. 2, which has the finest grain size of US '358 is No. 8.9 (18.3 μm). There is no disclosure of a prior austenite grain size of a hardened layer formed on

the surface of the steel product by induction hardening being 12 μm or less through the thickness of the hardened layer in US '358 as the Applicants recite in Claim 3.

The Applicants respectfully submit that US '105 is also inapplicable, whether taken individually or collectively with US '358. All of the US '105 steels contain Cr of 0.55~1.53% as tabulated in Table 1 and Table 2. The stated range is 0.4 to 1.8. Thus, there is no disclosed restriction on the Cr content as 0.2% or less as recited in Claims 1-12 and 17-20.

US '105 discloses steel having the finest grain size γ which is 11.3 (about 7.9 μm) in No. 72 tabulated in Table 5 for preventing coarsening of prior austenite grain size at the time of carburizing. Nonetheless, there is no disclosure specifying a prior austenite grain size of 12 μm or less at the time of induction hardening, which is quite dissimilar to the carburizing process used by the Applicants. The Applicants respectfully submit that combining US '105 with US '358 would still fail to teach the subject matter of Claims 3 and 5 and other claims depending therefrom.

There are still further differences as set forth below.

Si increases the number of nucleation sites of austenite during induction heating, inhibits the grain growth of austenite and thereby decreases the grain size of the hardened layer. Furthermore, Si inhibits the formation of carbides and, therefore, prevents a reduction in the grain boundary strength. Si is also suitable for the formation of bainite. Thus, Si is very effective in increasing the torsional fatigue strength. However, when the Si content is low, the prior austenite grain size through the thickness of the hardened layer cannot be decreased to 12 μm or less under any condition for manufacturing a steel product and any induction hardening condition. Hence, high torsional fatigue strength is unable to be obtained.

The foregoing are apparent from No. 36 in Table 2-1. In No. 36 in Table 2-1, there is tabulated a result of induction hardening effected within the scope of the Applicants' claims to steel Y of 0.28% Si, which is tabulated in Table 1, and therein, prior austenite grain size of a hardened layer is 15.5 μm and a grain size of 12 μm or less is not obtained. The torsional fatigue strength obtained is of a low value as a result.

The Applicants' steels before induction hardening have a structure of bainite or martensite and, since carbides disperse more finely in bainite or martensite than in ferrite + pearlite, when the total volume fraction of bainite and martensite in a steel product is at least 10% before induction hardening, the area of ferrite/carbide interface, which is the nucleation site of austenite during

induction heating, increases. As a result, austenite becomes fine and, consequently, this decreases the grain size of the hardened layer, increases the grain boundary strength, and thus increases the torsional fatigue strength.

Controlling the chemical composition of a steel product within a proper range and changing the prior austenite grain size through the thickness of a hardened layer formed by induction hardening to 12 μm or less increases the torsional fatigue strength remarkably. Steel having the above-mentioned composition is processed by hot working, such as rolling or forging, into a predetermined shape, and then cooling at an average cooling rate of at least 0.2 $^{\circ}\text{C/s}$ to yield a steel product. The steel product has a structure of bainite and/or martensite and is suitable for induction hardening, the total volume fraction of bainite and martensite being at least 10%.

The steel product for induction hardening having the composition and the structure as described above is cold rolled, cold forged or cut, if necessary, and subjected to induction hardening at least once. The final induction hardening is performed at a heating temperature of 800-1000 $^{\circ}\text{C}$. The induction hardened member thus manufactured has the prior austenite grain size of 12 μm or less through the thickness of the hardened layer formed on the surface of the steel product and exhibits high torsional fatigue strength. The grain size of the hardened layer is further decreased by repetitive induction hardening which is effected more than two times. In the repetitive induction hardening, when not only the heating temperature of the final induction hardening, but also the other heating temperatures are at 800-1000 $^{\circ}\text{C}$, the grain size of the hardened layer can be further decreased as can be seen in Nos. 2 and 5, for example, in Table 2-1. The Applicants therefore respectfully submit that US '105 and US '358 are inapplicable to Claims 1-12 and 17-20.

However, there is more.

B enhances the formation of bainite or martensite before induction hardening. As an effect of this, the prior austenite grain structure in the induction hardened layer after induction hardening becomes fine and this increases the grain boundary strength and the torsional fatigue strength. Further, a small quantity of B improves the induction hardenability, increases the thickness of a hardened layer, and thus increases the torsional fatigue strength. Furthermore, B segregates preferentially at the grain boundary and decreases the concentration of P segregated at the grain boundary, thereby increasing the grain boundary strength and the torsional fatigue strength. Because of the foregoing, B is a substantially effective element in improving the torsional fatigue strength.

Cr stabilizes carbides and thus enhances the formation of carbides at the grain boundary, decreases the grain boundary strength, and thus decreases the torsional fatigue strength. Accordingly, the Cr content is limited to 0.2 mass% or less and is more preferably as low as possible. Because of the foregoing, limiting Cr is substantially important in improving torsional fatigue strength.

Controlling the chemical composition of a steel product within a proper range and adjusting the prior austenite grain size through the thickness of a hardened layer formed by induction hardening to 12 μm or less substantially increases the torsional fatigue strength. By controlling the thickness of a hardened layer formed on the surface of the steel product by induction hardening to become 2 mm or more, excellent torsional fatigue strength is able to be secured.

The steel product for induction hardening having the composition in a range and the structure as described above is cold rolled, cold forged or cut, if necessary, and subjected to induction hardening at least once. The final induction hardening is performed at a heating temperature of 800-1000 °C. The induction hardened member thus manufactured has the prior austenite grain size of 12 μm or less through the thickness of the hardened layer formed on the surface of the steel product and exhibits high torsional fatigue strength. The grain size of the hardened layer is further decreased by repetitive induction hardening. In the repetitive induction hardening, not only the heating temperature of the final induction hardening, but also the other heating temperatures are set at 800-1000 °C, and a further decrease of the grain size of the hardened layer can be secured as in the case of Nos. 2 and 5, for example, in Table 2-1. Withdrawal of the rejection of Claims 1-12 and 17-20 is respectfully requested.

Claims 13-16 stand rejected over the further combination of JP '937 with US '105 and US '358. The Applicants respectfully submit that the further combination of JP '937 with the primary and secondary references does nothing to cure the deficiency set forth above.

US '358 does not contain the concept of a structure of bainite and/or martensite and the total volume fraction of bainite and martensite being 10% or more as in Claims 13-16. From the manufacturing process set out in US '358, namely, spheroidizing annealing → cold forging → lathe turning and component rolling → induction hardening, the structure is not a bainite and/or martensite structure.

The prior austenite grain size of Steel No. 2, which has the finest grain size of US '358, is 8.9 (18.3 μm). There is no disclosure of a prior austenite grain size of a hardened layer formed on the surface of the steel product by induction hardening being 12 μm or less through the thickness of the hardened layer.

Si increases the number of nucleation sites of austenite during induction heating, inhibits the grain growth of austenite, and thereby decreases the grain size of the hardened layer. Furthermore, Si inhibits the formation of carbides and therefore prevents a reduction in the grain boundary strength. Si is also suitable for the formation of bainite. Thus, Si is very effective in increasing the torsional fatigue strength. However, when the Si content is low, the prior austenite grain size through the thickness of the hardened layer is decreased to 12 μm or less under any condition for manufacturing a steel product and any induction hardening condition. Hence, high torsional fatigue strength is unable to be obtained. The foregoing are apparent from No. 36 in Table 2-1. In No. 36 in Table 2-1, there is tabulated a result of induction hardening effected within the Applicants' range to steel Y of 0.28% Si, which is tabulated in Table 1, and therein, prior austenite grain size of a hardened layer is 15.5 μm and a grain size of 12 μm or less is not obtained. The torsional fatigue strength obtained is of a low value as a result.

The Applicants' steel before induction hardening has a structure of bainite and/or martensite and since carbides disperse more finely in bainite or martensite than in ferrite + pearlite, when the total volume fraction of bainite and martensite in a steel product is at least 10% before induction hardening, the area of ferrite/carbide interface, which is a nucleation site of austenite during induction heating, increases and thereby the resulting austenite becomes fine and, consequently, this decreases the grain size of the hardened layer, increases the grain boundary strength, and thus increases the torsional fatigue strength.

Controlling the chemical composition of a steel product within a proper range and changing the prior austenite grain size through the thickness of a hardened layer formed by induction hardening to 12 μm or less remarkably increase the torsional fatigue strength.

The Applicants' steels are processed by hot working, such as rolling or forging, into a predetermined shape, and then cooled at an average cooling rate of at least 0.2 $^{\circ}\text{C/s}$ to yield a steel product. That steel product has a structure of bainite and/or martensite and is suitable for induction hardening, the total volume fraction of bainite and martensite being at least 10 %.

The steel product for induction hardening having the composition and the structure as described above is cold rolled, cold forged or cut, if necessary, and subjected to induction hardening at least once. The final induction hardening is performed at a heating temperature of 800-1000 °C. The induction hardened member thus manufactured has the prior austenite grain size of 12 μm or less through the thickness of the hardened layer formed on the surface of the steel product and exhibits high torsional fatigue strength. The grain size of the hardened layer is further decreased by repetitive induction hardening which is effected more than two times. In the repetitive induction hardening, when not only the heating temperature of the final induction hardening, but also the other heating temperatures are preferably 800-1000 °C, the grain size of the hardened layer can be further decreased as can be seen in Nos. 2 and 5 and so forth in Table 2-1.

The heating time of induction hardening is 5 seconds or less to inhibit the grain growth of austenite and decrease the grain size of the hardened layer significantly.

US '105 is inapplicable for the reasons previously stated above. Hypothetically combining JP '937 with the other two disclosures does not cure the problems associated with the primary and secondary references.

Steel Nos. 1 to 6 and Steel Nos. 8 to 15 and comparative Steel Nos. 1 to 7, all tabulated in Table 1 of JP '937 contain Si: 0.07 to 0.29% and the value is outside the claimed range. Steel No. 7 contains Si: 0.49% which is within the Applicants' claimed range. However, Cr is present in an amount of 0.98% and this deviates from the Applicants' claimed range. Thus, making this hypothetical combination with the primary and secondary references would simply not be helpful. The compositions are not the same and deviate significantly from that claimed such as with respect to Cr. The Applicants have already established the problems associated with varying the composition and the expectation of the bainite and/or martensite characteristics. Therefore, further hypothetically combining JP '937 with the primary and secondary references would still result in structures and methodology different from what the Applicants claim in Claims 13-16. Withdrawal of the rejection is respectfully requested.

In light of the foregoing, the Applicants respectfully submit that the entire Application is now in condition for allowance, which is respectfully requested.

Respectfully submitted,



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